Organ specific averaged SAR near multiple-frequency base station antennas

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SHORT ABSTRACT

This study determines the organ specific averaged SAR (SAR_{osa}) near multiple-frequency base station antennas. The SAR_{osa} is assessed numerically in the vicinity of a base station antenna emitting at 4 frequencies using FDTD simulations with the virtual family male. A clear frequency dependence of SAR_{osa} exists, as the penetration depth of electromagnetic radiation decreases at higher frequencies will decrease and cause the SAR in inner tissues to decrease. Based on the ICNIRP basic restrictions for the general public, cerebrospinal fluid shows the highest possible SAR_{osa}= -4.8 dBW/kg (at 800 MHz) and the pons (part of the brain stem) experiences the lowest maximal SAR_{osa}= -18.8 dBW/kg in front of the BSA.

INTRODUCTION

Base station antennas (BSAs) transmit radio frequency (RF) radiation that exposes workers and the general population. In order to protect these people, ICNIRP [1] has defined basic restrictions on the whole-body averaged specific absorption rate (SAR_{wb}) and the peak 10 g averaged SAR (SAR_{10g}) and reference levels for the emitted electromagnetic fields. While a study of SAR_{wb} and SAR_{10g} near BSAs is necessary to determine compliance with the basic restrictions, this does not provide any information about the absorption in the different tissues of the body. For that purpose the organ specific SAR (SAR_{osa}) should be studied. This quantity has already been studied in heterogeneous phantoms placed in front of a BSA emitting at 900 MHz [2], but never for multiple frequency exposure or other directions with respect to BSAs.

MATERIALS AND METHODS

This study aims to determine the SAR_{osa} near multiple-frequency base station antennas. To this aim finite difference time domain (FDTD) simulations are done using the virtual family male (VFM) [3]. The dielectric properties of the VFM's tissues are obtained from the Gabriel database [4]. The VFM is brought in the vicinity of a base station antenna emitting at 4 frequencies (800, 900, 1800 and 2600 MHz). The characteristics of the antenna are listed in Table 1. The patch antennas emitting at 800 and 900 MHz are spread over the full length of the antenna, while the patch antennas emitting at 1800 and 2600 MHz are only found at the lower and upper half, respectively. Three directions of the VFM regarding the BSA have been studied: in front of, at the side and at the back of the BSA. The VFM is always facing the antenna and is vertically and horizontally centered with respect to the BSA. Both single frequency and multiple frequency (cumulative) exposure scenarios are considered. For the study of SAR_{osa} the different tissues of the VFM's brain are considered.

Frequency (MHz)	Gain (dBi)	Horizontal beam width -3dB (°)	Vertical beam width -3dB (°)	Length (m)	Number of radiating patch antennas
800	12.2	73	14.9	1.4	5
900	12.9	67	13.9		5
1800	14.1	68	13.3		3
2600	14.2	84	11.5		6

Table 1: Antenna characteristics of the studied antenna.

The BSA will emit at a certain output power P, inducing electric fields inside the phantom. These can be used to calculate the whole-body averaged SAR, peak 10 g averaged SAR and SAR_{osa}. The SAR values will be dependent on the BSA's output power (P), the emitted frequency (f) and the distance (d) between the VFM and the BSA. ICNIRP defines basic restrictions for these SAR values for both the general public and occupational exposure [1], which will limit the allowed output power. The allowed power: P^{x}_{compl} (d,f), with x=SAR_{wb} or SAR_{10g}, will thus be determined by comparing $SAR_{wb/10g}$ with the basic restrictions and will be dependent on the emitted frequency, the distance from and the orientation towards the antenna.

RESULTS

The allowed powers based on the peak 10 g averaged SAR in the head and trunk and limbs, as well as the allowed powers based on the whole-body averaged SAR have been determined in front of and at the side and back of the BSA. At every position the minimally allowed power $min_{x}(P^{x}_{compl}$ (d,f)) is determined, as this output power will ensure compliance with all basic restrictions. Simultaneously the SAR_{osa} for 1 W of output power has been simulated at the same locations. The product of the SAR_{osa} with the minimal allowed power will result in the maximally allowed SAR_{osa} near the BSA. Figure 1 shows the maximally allowed SAR_{osa} in front of the antenna for the different frequencies, for different cerebral tissues. The values for occupational exposure are a factor 5 (7 dB) higher.

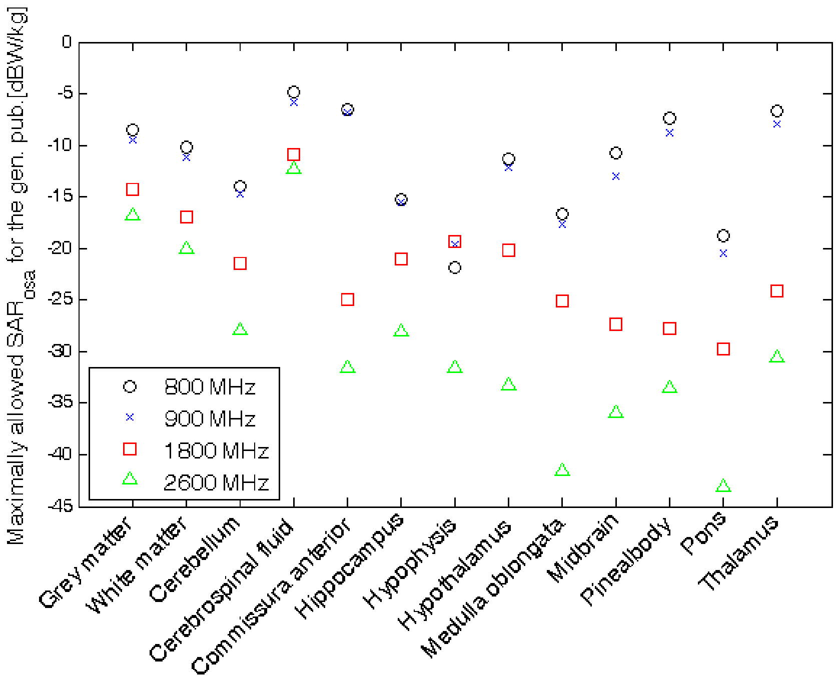

Figure 1: Maximally allowed SAR_{osa} based on the ICNIRP basic restrictions for the general public, for different tissues of the VFM's brain in front of the investigated BSA.

Figure 1 shows that the different tissues will exhibit different maximally allowed values, due to the differences in dielectric properties and location in the phantom. The cerebrospinal fluid shows the highest possible SAR_{osa}= -4.8 dBW/kg (at 800 MHz) and the pons (part of the brain stem) experiences the lowest maximal SAR_{osa}= -18.8 dBW/kg for the general public in front of the BSA. A clear frequency dependence exists: the maximally SAR always occurs at 800 MHz (except for the hypophysis at 1800 MHz), while the minimal SAR always occurs at 2600 MHz. At higher frequencies the penetration depth of electromagnetic radiation decreases, causing the SAR in inner organs to decrease and the SAR in the skull and skin to increase. The values at 2600 MHz are larger than expected because the phantom's skull is placed in front of the patch antennas emitting at 2600 MHz. The Pineal body/gland shows the largest frequency dependence as there is a 26.2 dB difference between the SAR_{osa} values at 800 and 2600 MHz. This difference is smallest for the cerebrospinal fluid, which exhibits a difference of 7.4 dB between the SAR_{osa} at 800 and 2600 MHz.

CONCLUSIONS

We have investigated the SAR_{wb}, SAR_{10g} both in head and trunk and in the limbs, and SAR_{osa} in the VFM phantom near a multiple-frequency base station antenna. The allowed powers based on the ICNIRP basic restrictions, are then used to calculate the maximally allowed SAR_{osa} values. The results for SAR_{oas} shows a strong frequency dependence.

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